ATENT COOPERATION TRE TY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing: 09 December 1999 (09.12.99)	
International application No.: PCT/AU99/00424	Applicant's or agent's file reference: 85148
International filing date: 02 June 1999 (02.06.99)	Priority date: 02 June 1998 (02.06.98)
Applicant: RYLATT, Dennis, Brian	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International preliminary Examining Authority on:

20 October 1999 (20.10.99)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was [ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	Authorized officer: J. Zahra Telephone No.: (41-22) 338.83.38

PCT/AU99/00424

TJD
CIB

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

F.B. RICE & CO.
605 Darling Street
Balmain, NSW 2041
AUSTRALIE

RECEIVED
14 APR 2000
F. B. RICE & CO.

Date of mailing (day/month/year) 04 April 2000 (04.04.00)	
Applicant's or agent's file reference 85148	**IMPORTANT NOTIFICATION**
International application No. PCT/AU99/00424	**International filing date** (day/month/year) 02 June 1999 (02.06.99)

1. The following indications appeared on record concerning:

[X] the applicant [X] the inventor [ ] the agent [ ] the common representative

Name and Address	State of Nationality	State of Residence
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[X] the person [X] the name [X] the address [X] the nationality [X] the residence

Name and Address	State of Nationality	State of Residence
LIM, Sharon 28/61-89 Buckingham Street Surry Hills, NSW 2010 Australia	AU	AU
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

3. Further observations, if necessary:
Added inventor and applicant for the purposes of the US only.

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[X] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[X] the elected Offices concerned
[ ] other:

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer D. Mülhausen Dorothée Mülhausen Telephone No.: (41-22) 338.83.38

Form PCT/IB/306 (March 1994)

003208014

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 85148	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).
International application No. **PCT/AU99/00424**	International filing date *(day/month/year)* 2 June 1999	Priority Date *(day/month/year)* 2 June 1998

International Patent Classification (IPC) or national classification and IPC

Int. Cl. [7] C07K 001/26

Applicant

GRADIPORE LIMITED et al

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

   [X] This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of **8** sheet(s).

3. This report contains indications relating to the following items:

I	[X]	Basis of the report
II	[ ]	Priority
III	[ ]	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV	[ ]	Lack of unity of invention
V	[X]	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	[ ]	Certain documents cited
VII	[ ]	Certain defects in the international application
VIII	[ ]	Certain observations on the international application

Date of submission of the demand 20 October 1999	Date of completion of the report 14 August 2000
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer I J Dowd. **IAN DOWD** Telephone No. (02) 6283 2273

I. Basis of the report

1. With regard to the **elements** of the international application:*
   - [ ] the international application as originally filed.
   - [X] the description, pages **5-11, 13,** as originally filed,
     pages , filed with the demand,
     pages **1-4, 12,** received on **27 June 2000** with the letter of **27 June 2000**
   - [X] the claims, pages , as originally filed,
     pages , as amended (together with any statement) under Article 19,
     pages , filed with the demand,
     pages **14-16,** received on **27 June 2000** with the letter of **27 June 2000**
   - [X] the drawings, pages **1-3,** as originally filed,
     pages , filed with the demand,
     pages , received on with the letter of
   - [ ] the sequence listing part of the description:
     pages , as originally filed
     pages , filed with the demand
     pages , received on with the letter of

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
   These elements were available or furnished to this Authority in the following language which is:
   - [ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).
   - [ ] the language of publication of the international application (under Rule 48.3(b)).
   - [ ] the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, was on the basis of the sequence listing:
   - [ ] contained in the international application in written form.
   - [ ] filed together with the international application in computer readable form.
   - [ ] furnished subsequently to this Authority in written form.
   - [ ] furnished subsequently to this Authority in computer readable form.
   - [ ] The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - [ ] The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

4. [ ] The amendments have resulted in the cancellation of:
   - [ ] the description, pages
   - [ ] the claims, Nos.
   - [ ] the drawings, sheets/fig.

5. [ ] This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

** *Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report*

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	**1-17**	**YES**
	Claims	**nil**	**NO**
Inventive step (IS)	Claims	**1-17**	**YES**
	Claims	**nil**	**NO**
Industrial applicability (IA)	Claims	**1-17**	**YES**
	Claims	**nil**	**NO**

2. Citations and explanations (Rule 70.7)

Citations

1. Journal of Chromatography A, 827 (1998) 329-335
"Purification of monoclonal antibodies from ascitic fluid using preparative electrophoresis"; S Lim et al

2. Electrophoresis, (1994), Vol.15 (7), pages 968-971
"Multifunctional apparatus for electrokinetic processing of proteins"; Z. Stephen Horvath et al

3. Electrophoresis, (1995), Vol.16 (1), pages 98-100
"Preparative reflux electrophoresis"; Joel Margolis et al

NOVELTY and INVENTIVE STEP

Document (1) was published after the priority date of the claims and before publication thereof. Upon perusal of the priority document, the claims are entitled to the priority date claimed. Therefore document (1) is excluded for the purposes of novelty and inventive step.

Document (2) discloses at Figure 1(a) a charge based electrophoretic separation of a target protein using known pH and differences in isoelectric points between contaminants and the protein. D2 exemplifies the separation of Hb (haemoglobin) from BSA (bovine serum albumin) as a specific separation to illustrate the separation effectiveness. Additionally, purification of phycoerythrin was effected with a yield over 85%. However, no specific disclosure of purifying antibodies is made in the citation, nor specific conditions for its purification, such as buffer and electrophoretic membrane characteristics. Therefore, the claims are considered to be novel in the light of D2.

With regard to inventive step, it is clearly not envisaged that the apparatus or method is solely for Hb or BSA. (See particularly page 968, column 2, lines 8-11). See also page 970, column 2 where various plant and mammalian proteins have been fractionated, and page 971, column 1 where it is clearly stated it is suitable for use in a wide range of macromolecules. A person skilled in the art faced with the problem of purifying an antibody would consider the process of the prior art as an obvious choice. However, the process of the present application produces antibodies that are less denatured than those obtained from methods of the prior art. Therefore, the process of the present application contains an advantage over that of the prior art and therefore enjoys an inventive step.

Continued on supplemental sheet

Supplemental Box V
(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of

Document (3) discloses "reflux electrophoresis" where the electric potential across the membrane is periodically stopped and reversed so as to clear the membrane.

Combining Document (2) with Document (3), as would be obvious to a person skilled in the art, results in the specific disclosure of the optional periodic stopping and reversal of the electric potential across the membrane to cause backward movement of the antibody out of the membrane. However, since Document (2) is novel and inventive, and the features disclosed in Document (3) relate to optional features of the application, Document (3) does not deny the application of novelty or inventive step.

INDUSTRIAL APPLICABILITY

The claims relate to a method of separation that has use in the biotechnology industry. Therefore the claims have industrial applicability.

RECD 19 SEP 2000
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PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 85148	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416).
International application No. **PCT/AU99/00424**	International filing date *(day/month/year)* 2 June 1999	Priority Date *(day/month/year)* 2 June 1998

International Patent Classification (IPC) or national classification and IPC

Int. Cl. 7 C07K 001/26

Applicant

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II	[ ]	Priority
III	[ ]	Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
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V	[X]	Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI	[ ]	Certain documents cited
VII	[ ]	Certain defects in the international application
VIII	[ ]	Certain observations on the international application

Date of submission of the demand 20 October 1999	Date of completion of the report 14 August 2000
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer I J Dowd. **IAN DOWD** Telephone No. (02) 6283 2273

I. Basis of the report

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   [ ] the international application as originally filed.

   [X] the description, pages **5-11, 13,** as originally filed,
   pages , filed with the demand,
   pages **1-4, 12,** received on **27 June 2000** with the letter of **27 June 2000**

   [X] the claims, pages , as originally filed,
   pages , as amended (together with any statement) under Article 19,
   pages , filed with the demand,
   pages **14-16,** received on **27 June 2000** with the letter of **27 June 2000**

   [X] the drawings, pages **1-3,** as originally filed,
   pages , filed with the demand,
   pages , received on with the letter of

   [ ] the sequence listing part of the description:
   pages , as originally filed
   pages , filed with the demand
   pages , received on with the letter of

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
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   [ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

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   [ ] the claims, Nos.

   [ ] the drawings, sheets/fig.

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** *Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report*

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims **1-17**	**YES**
	Claims **nil**	**NO**
Inventive step (IS)	Claims **1-17**	**YES**
	Claims **nil**	**NO**
Industrial applicability (IA)	Claims **1-17**	**YES**
	Claims **nil**	**NO**

2. Citations and explanations (Rule 70.7)

Citations

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"Purification of monoclonal antibodies from ascitic fluid using preparative electrophoresis"; S Lim et al

2. Electrophoresis, (1994), Vol.15 (7), pages 968-971
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"Preparative reflux electrophoresis"; Joel Margolis et al

NOVELTY and INVENTIVE STEP

Document (1) was published after the priority date of the claims and before publication thereof. Upon perusal of the priority document, the claims are entitled to the priority date claimed. Therefore document (1) is excluded for the purposes of novelty and inventive step.

Document (2) discloses at Figure 1(a) a charge based electrophoretic separation of a target protein using known pH and differences in isoelectric points between contaminants and the protein. D2 exemplifies the separation of Hb (haemoglobin) from BSA (bovine serum albumin) as a specific separation to illustrate the separation effectiveness. Additionally, purification of phycoerythrin was effected with a yield over 85%. However, no specific disclosure of purifying antibodies is made in the citation, nor specific conditions for its purification, such as buffer and electrophoretic membrane characteristics. Therefore, the claims are considered to be novel in the light of D2.

With regard to inventive step, it is clearly not envisaged that the apparatus or method is solely for Hb or BSA. (See particularly page 968, column 2, lines 8-11). See also page 970, column 2 where various plant and mammalian proteins have been fractionated, and page 971, column 1 where it is clearly stated it is suitable for use in a wide range of macromolecules. A person skilled in the art faced with the problem of purifying an antibody would consider the process of the prior art as an obvious choice. However, the process of the present application produces antibodies that are less denatured than those obtained from methods of the prior art. Therefore, the process of the present application contains an advantage over that of the prior art and therefore enjoys an inventive step.

Continued on supplemental sheet

Supplemental Box V
(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of

Document (3) discloses "reflux electrophoresis" where the electric potential across the membrane is periodically stopped and reversed so as to clear the membrane.

Combining Document (2) with Document (3), as would be obvious to a person skilled in the art, results in the specific disclosure of the optional periodic stopping and reversal of the electric potential across the membrane to cause backward movement of the antibody out of the membrane. However, since Document (2) is novel and inventive, and the features disclosed in Document (3) relate to optional features of the application, Document (3) does not deny the application of novelty or inventive step.

INDUSTRIAL APPLICABILITY

The claims relate to a method of separation that has use in the biotechnology industry. Therefore the claims have industrial applicability.

CLAIMS:

1. A method of separation of an antibody from a mixture of the antibody and at least one contaminant, the method comprising:

(a) placing the antibody and contaminant mixture in a first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane;

(b) selecting a pH for the first solvent stream such that contaminants with an isoelectric point (p*I*) lower than the antibody to be separated will be charged:

(c) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(d) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re-enter first solvent stream; and

(e) repeating step (c) and optionally step (d) until the first solvent stream contains the desired purity of antibody.

2. The method according to claim 1 wherein the antibody and contaminant mixture is a monoclonal antibody in ascitic fluid.

3. The method according to claim 1 or 2 wherein the electrophoretic membrane has a molecular mass cut-off of 50 to 150 kDa.

4. The method according to claim 3 wherein the electrophoretic membrane has a molecular mass cut-off of 100 kDa.

5. The method according to any one of claims 1 to 4 wherein the pH of the first solvent stream is 7.5 to 9.5.

6. The method according to any one of claims 1 to 5 further including the steps of:

(f) placing the separated antibody in a fresh first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane;

(g) selecting a pH of the fresh first solvent stream such that the pH is within 1 pH unit of the p*I* of the antibody:

REPLACED BY ART 34 AMDT

(h) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the fresh first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(i) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the fresh first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re-enter fresh first solvent stream; and

(j) repeating step (h) and optionally step (i) until the fresh first solvent stream contains the desired purity of antibody.

7. The method according to claim 6 wherein the molecular mass cut-off of the membrane used in step (f) is larger than that used in step (b).

8. The method according to claim 7 wherein the molecular mass cut-off of the electrophoretic membrane used in step (f) is at least 200 kDa.

9. The method according to claim 8 wherein the molecular mass cut-off of the electrophoretic membrane used in step (f) is 1000 kDa.

10. The method according to any one of claims 6 to 9 wherein the pH in step (g) is from 6 to 8.

11. The method according any one of claims 6 to 9 wherein the pH in step (g) is within 0.5 pH units of the p*I* of the antibody.

12. The method according to any one of claims 1 to 11 wherein percent recovery of the antibody is at least 70%.

13. The method according to claim 12 wherein percent recovery of the antibody is at least 90%.

14. A method of separation of an antibody from a mixture of the antibody and at least one contaminant, the method comprising:

(a) placing the separated antibody in a first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane;

(b) selecting a pH of the first solvent stream such that the pH is within 1 pH unit of the p*I* of the antibody;

(c) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the

REPLACED BY ART 34 AMDT

first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(d) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re-enter first solvent stream; and

(e) repeating step (c) and optionally step (d) until the first solvent stream contains the desired purity of antibody.

15. The method according to claim 14 wherein the antibody and contaminant mixture is a monoclonal antibody in ascitic fluid.

16. The method according to claim 14 or 15 wherein the molecular mass cut-off of the electrophoretic membrane used in step (a) is at least 200 kDa.

17. The method according to claim 16 wherein the molecular mass cut-off of the electrophoretic membrane used in step (a) is 1000 kDa.

18. The method according to any one of claims 14 to 17 wherein the pH in step (b) is from 6 to 8.

19. The method according to any one of claims 14 to 17 wherein the pH in step (b) is within 0.5 pH units of the p*I* of the antibody.

20. An antibody purified by the method according to any one of claims 1 to 19.

21. The antibody according to claim 20 being a monoclonal antibody.

REPLACED BY
ART 34 AMDT

Table 3. Yield of Rat IgG2b monoclonal antibody

Purification Method	Yield (%)
Protein-G	83
Invention	91
Ion exchange	81

Electrophoretic analysis (SDS-PAGE) of antibodies purified by the present invention revealed lower number of protein bands indicating that the present method does not cleave or damage the antibodies compared with other purification techniques. Not only can the present invention provide greater yields of antibody, the invention also provides more active and less denatured antibody preparations.

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

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ART 34 AMDT

525 Rec'd PCT/PTO 01 DEC 2000

Purification of Antibodies

Technical Field

The present invention relates to methods suitable for purification of antibodies, particularly monoclonal antibodies from ascites fluid.

Background Art

The processing of complex biological solutions is a major bottleneck in the biotechnology industry and there is a strong demand for cost effective technologies for the purification of naturally occurring and recombinant proteins. This is particularly true for antibodies including monoclonal antibodies, where there has been an on-going search for simple generic methods of purification. In particular, monoclonal antibodies have had an increasing number of research, therapeutic and diagnostic applications since their initial production in 1975. The difficulties in bioprocessing have meant that recoveries of monoclonal antibodies in existing purification schemes are rarely reported but are often in the range of 10 to 70%. Although new processes have become increasingly effective in terms of yield and recovery, commonly used processes often utilise harsh pH or ionic strength conditions for elution which may not always be compatible with maintaining maximal biological activity of antibodies.

The present inventor has found that preparative electrophoresis using Gradiflow technology (AU 601040) is particularly suitable for the purification of antibodies. In contrast to conventional methods, Gradiflow uses mild, non-denaturing buffers and conditions which may be utilised to produce more active antibody preparations.

Disclosure of Invention

In a first aspect, the present invention consists in a method of separation of an antibody from a mixture of the antibody and at least one contaminant, the method comprising:

(a) placing the antibody and contaminant mixture in a first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane;

(b) selecting a pH for the first solvent stream such that contaminants with an isoelectric point (p*I*) lower than the antibody to be separated will be charged;

(c) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into

REPLACED BY
ART 34 AMDT

the second solvent stream while the antibody is substantially retained in the first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(d) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re-enter first solvent stream: and

(e) repeating step (c) and optionally step (d) until the first solvent stream contains the desired purity of antibody.

Preferably, the antibody and contaminant mixture is a monoclonal antibody in ascitic fluid.

In a preferred embodiment of the first aspect of the present invention, the electrophoretic membrane has a molecular mass cut-off of about 50 to 150 kDa, preferably about 100 kDa. The p*I* of the antibody to be separated is usually obtained by isoelectric focusing (IEF). The pH of the first solvent stream is preferably about 7.5 to 9.5. Major protein contaminants, including albumin whose p*I* is well known to be 4.9, can be separated from the antibodies by being caused to transfer into the second solvent stream at pH 8.3.

In a second aspect, the present invention consists in a method of separation of an antibody from a mixture of the antibody and at least one contaminant, the method comprising:

(a) placing the separated antibody in a first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane;

(b) selecting a pH of the first solvent stream such that the pH is within 1 pH unit of the p*I* of the antibody;

(c) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(d) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the first solvent stream, wherein substantially not causing any

contaminants that have entered the second solvent stream to re-enter first solvent stream; and

(e) repeating step (c) and optionally step (d) until the first solvent stream contains the desired purity of antibody.

The electrophoretic membrane in step (a) preferably has a molecular mass cut-off at least about 200 kDa to ensure the contaminants can pass through to the second solvent stream. A cartridge containing a large 1000 kDa pore size separating-membrane has been found to be particularly suitable for this aspect of the present invention. The pH in step (b) is typically from about 6 to 8.0. It will be appreciated that the pH of the buffer will depend on the p*I* of the antibody to be purified and the p*I*s of the contaminants.

The pH of the buffer used in step (b) can be above or below the p*I* of the antibody to be separated. Preferably, the pH is within 0.5 pH units of the p*I* of the antibody.

In a third aspect, the present invention consists in a method of separation of an antibody from a mixture of the antibody and at least one contaminant, the method comprising:

(a - e) separating the antibody according to the first aspect of the present invention;

(f) placing the separated antibody in a fresh first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane;

(g) selecting a pH of the fresh first solvent stream such that the pH is within 1 pH unit of the p*I* of the antibody;

(h) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the fresh first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(i) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the fresh first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re-enter first solvent stream; and

REPLACED BY ART 34 AMDT

(j) repeating step (h) and optionally step (i) until the fresh first solvent stream contains the desired purity of antibody.

The molecular mass cut-off of the electrophoretic membrane used in step (f) is preferably larger than the membrane used in step (b). The electrophoretic membrane in step (f) preferably has a molecular mass cut-off at least about 200 kDa to ensure the contaminants can pass through to the second solvent stream. A cartridge containing a large 1000 kDa pore size separating-membrane has been found to be particularly suitable for this aspect of the present invention. The pH in step (g) is typically from about 6 to 8.0. It will be appreciated that the pH of the buffer will depend on the p*I* of the antibody to be purified and the p*I*s of the contaminants.

The pH of the buffer used in step (g) can be above or below the p*I* of the antibody to be separated. Preferably, the pH is within 0.5 pH units of the p*I* of the antibody.

The present inventor has been able to obtain percent recoveries of monoclonal antibodies from ascitic fluid of at least 70% and often greater than 90% using the methods according to the present invention.

In a fourth aspect, the present invention consists in use of Gradiflow in the purification and/or separation of antibodies.

In a fifth aspect, the present invention consists in an antibody purified by the method according to the first, second or third aspects of the present invention.

Throughout this specification, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

In order that the present invention may be more clearly understood, preferred forms will be described in the following examples with reference to the accompanying drawings.

<u>Brief Description of Drawings</u>

Figure 1 shows the operating modes of the Gradiflow separating cartridge. (a) Sized-based separation - this is a first step in which major contaminants are removed downstream from antibody mixture upstream. (b) Charge-based separation - this is a second step suitable to remove any residual contaminants if requiring antibodies of higher purity.

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Purification of Antibodies

Technical Field

The present invention relates to methods suitable for purification of antibodies, particularly monoclonal antibodies from ascites fluid.

Background Art

The processing of complex biological solutions is a major bottleneck in the biotechnology industry and there is a strong demand for cost effective technologies for the purification of naturally occurring and recombinant proteins. This is particularly true for antibodies including monoclonal antibodies, where there has been an on-going search for simple generic methods of purification. In particular, monoclonal antibodies have had an increasing number of research, therapeutic and diagnostic applications since their initial production in 1975. The difficulties in bioprocessing have meant that recoveries of monoclonal antibodies in existing purification schemes are rarely reported but are often in the range of 10 to 70%. Although new processes have become increasingly effective in terms of yield and recovery, commonly used processes often utilise harsh pH or ionic strength conditions for elution which may not always be compatible with maintaining maximal biological activity of antibodies.

The present inventor has found that preparative electrophoresis using Gradiflow technology (AU 601040) is particularly suitable for the purification of antibodies. In contrast to conventional methods, Gradiflow uses mild, non-denaturing buffers and conditions which may be utilised to produce more active antibody preparations.

Disclosure of Invention

In a first aspect, the present invention consists in a method of separation of an antibody from a mixture of the antibody and at least one contaminant, the method comprising:

(a) placing the antibody and contaminant mixture in a first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane;

(b) selecting a pH for the first solvent stream such that contaminants with an isoelectric point (p*I*) lower than the antibody to be separated will be charged;

(c) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into

the second solvent stream while the antibody is substantially retained in the first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(d) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re-enter first solvent stream; and

(e) repeating step (c) and optionally step (d) until the first solvent stream contains the desired purity of antibody.

Preferably, the antibody and contaminant mixture is a monoclonal antibody in ascitic fluid.

In a preferred embodiment of the first aspect of the present invention, the electrophoretic membrane has a molecular mass cut-off of about 50 to 150 kDa, preferably about 100 kDa. The p*I* of the antibody to be separated is usually obtained by isoelectric focusing (IEF). The pH of the first solvent stream is preferably about 7.5 to 9.5. Major protein contaminants, including albumin whose p*I* is well known to be 4.9, can be separated from the antibodies by being caused to transfer into the second solvent stream at pH 8.3.

In a second aspect, the present invention consists in a method of separation of an antibody from a mixture of the antibody and at least one contaminant, the method comprising:

(a) placing the separated antibody in a first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane;

(b) selecting a pH of the first solvent stream such that the pH is within 1 pH unit of the p*I* of the antibody;

(c) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(d) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the first solvent stream, wherein substantially not causing any

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contaminants that have entered the second solvent stream to re-enter first solvent stream; and

(e) repeating step (c) and optionally step (d) until the first solvent stream contains the desired purity of antibody.

The electrophoretic membrane in step (a) preferably has a molecular mass cut-off at least about 200 kDa to ensure the contaminants can pass through to the second solvent stream. A cartridge containing a large 1000 kDa pore size separating-membrane has been found to be particularly suitable for this aspect of the present invention. The pH in step (b) is typically from about 6 to 8.0. It will be appreciated that the pH of the buffer will depend on the p*I* of the antibody to be purified and the p*I*s of the contaminants.

The pH of the buffer used in step (b) can be above or below the p*I* of the antibody to be separated. Preferably, the pH is within 0.5 pH units of the p*I* of the antibody.

In a third aspect, the present invention consists in a method of separation of an antibody from a mixture of the antibody and at least one contaminant, the method comprising:

(a - e) separating the antibody according to the first aspect of the present invention;

(f) placing the separated antibody in a fresh first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane;

(g) selecting a pH of the fresh first solvent stream such that the pH is within 1 pH unit of the p*I* of the antibody;

(h) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the fresh first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(i) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the fresh first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re-enter first solvent stream; and

(j) repeating step (h) and optionally step (i) until the fresh first solvent stream contains the desired purity of antibody.

The molecular mass cut-off of the electrophoretic membrane used in step (f) is preferably larger than the membrane used in step (b). The electrophoretic membrane in step (f) preferably has a molecular mass cut-off at least about 200 kDa to ensure the contaminants can pass through to the second solvent stream. A cartridge containing a large 1000 kDa pore size separating-membrane has been found to be particularly suitable for this aspect of the present invention. The pH in step (g) is typically from about 6 to 8.0. It will be appreciated that the pH of the buffer will depend on the p*I* of the antibody to be purified and the p*I*s of the contaminants.

The pH of the buffer used in step (g) can be above or below the p*I* of the antibody to be separated. Preferably, the pH is within 0.5 pH units of the p*I* of the antibody.

The present inventors have been able to obtain percent recoveries of monoclonal antibodies from ascitic fluid of at least 70% and often greater than 90% using the methods according to the present invention.

A significant advantage of the present invention is that the separated antibody is less denatured or altered compared with the same antibody obtained by conventional antibody purification methods such as salt precipitation, Protein-A, Protein-G and ion-exchange chromatography.

In a fourth aspect, the present invention consists in use of Gradiflow in the purification and/or separation of antibodies.

In a fifth aspect, the present invention consists in an antibody purified by the method according to the first, second or third aspects of the present invention.

In order that the present invention may be more clearly understood, preferred forms will be described in the following examples with reference to the accompanying drawings.

Brief Description of Drawings

Figure 1 shows the operating modes of the Gradiflow separating cartridge. (a) Sized-based separation - this is a first step in which major contaminants are removed downstream from antibody mixture upstream. (b) Charge-based separation - this is a second step suitable to remove any residual contaminants if requiring antibodies of higher purity.

Table 3. Yield of Rat IgG2b monoclonal antibody

Purification Method	Yield (%)
Protein-G	83
Invention	91
Ion exchange	81

Electrophoretic analysis (SDS-PAGE) of antibodies purified by the present invention revealed lower number of protein bands indicating that the present method does not cleave or damage the antibodies compared with other purification techniques. Not only can the present invention provide greater yields of antibody, the invention also provides more active and less denatured antibody preparations.

Throughout this specification, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

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CLAIMS:

1. A method of separating an antibody from a mixture of antibody and at least one contaminant, the method comprising:

(a) placing the antibody and contaminant mixture in a first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane having a molecular mass cut-off of 50 to 150 kDa;

(b) selecting a pH of 7.5 to 9.5 for the first solvent stream such that contaminants with an isoelectric point (p*I*) lower than the antibody to be separated will be charged;

(c) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(d) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re-enter the first solvent stream; and

(e) repeating step (c) and optionally step (d) until the first solvent stream contains the desired purity of antibody, wherein the recovery of the antibody is at least 70% and the antibody being less denatured or altered compared with the same antibody obtained by conventional antibody purification methods.

2. The method according to claim 1 wherein the antibody and contaminant mixture is a monoclonal antibody in ascitic fluid.

3. The method according to claim 1 or 2 wherein the electrophoretic membrane has a molecular mass cut-off of 100 kDa.

4. The method according to any one of claims 1 to 3 further including the steps of:

(f) placing the separated antibody in a fresh first solvent stream, the fresh first solvent stream being separated from a second solvent stream by an electrophoretic membrane having a molecular mass cut-off larger than that of the electrophoretic membrane used in step (b);

(g) selecting a pH of the fresh first solvent stream such that the pH is within 1 pH unit of the p*I* of the antibody;

(h) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the fresh first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(i) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the fresh first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re-enter the fresh first solvent stream; and

(j) repeating step (h) and optionally step (i) until the fresh first solvent stream contains the desired purity of antibody, wherein the recovery of the antibody is at least 70%.

5. The method according to claim 4 wherein the molecular mass cut-off of the electrophoretic membrane used in step (f) is at least 200 kDa.

6. The method according to claim 4 wherein the molecular mass cut-off of the electrophoretic membrane used in step (f) is 1000 kDa.

7. The method according to any one of claims 4 to 6 wherein the pH of the fresh first solvent stream in step (g) is from 6 to 8.

8. The method according any one of claims 4 to 6 wherein the pH of the fresh first solvent stream in step (g) is within 0.5 pH units of the p*I* of the antibody.

9. The method according to any one of claims 1 to 8 wherein recovery of the antibody is at least 90%.

10. A method of separating an antibody from a mixture of antibody and at least one contaminant, the method comprising:

(a) placing the antibody and contaminant mixture in a first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane having a molecular mass cut-off of at least 200 kDa;

(b) selecting a pH of the first solvent stream such that the pH is within 1 pH unit of the p*I* of the antibody;

(c) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the

first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(d) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re-enter the first solvent stream; and

(e) repeating step (c) and optionally step (d) until the first solvent stream contains the desired purity of antibody, wherein the recovery of the antibody is at least 70% and the antibody being less denatured or altered compared with the same antibody obtained by conventional antibody purification methods.

11. The method according to claim 10 wherein the antibody and contaminant mixture is a monoclonal antibody in ascitic fluid.

12. The method according to claim 10 or 11 wherein the molecular mass cut-off of the electrophoretic membrane used in step (a) is 1000 kDa.

13. The method according to any one of claims 10 to 12 wherein the pH of the first solvent stream in step (b) is from 6 to 8.

14. The method according to any one of claims 10 to 12 wherein the pH of the first solvent stream in step (b) is within 0.5 pH units of the *pI* of the antibody.

15. The method according to any one of claims 10 to 14 wherein recovery of the antibody is at least 90%.

16. An isolated antibody purified by the method according to any one of claims 1 to 15.

17. The isolated antibody according to claim 16 being a monoclonal antibody.

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(57) Abstract

A method of separation of an antibody from a mixture of the antibody and at least one contaminant, the method comprising: a) placing the antibody and contaminant mixture in a first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane; b) selecting the pH for the first solvent stream such that contaminants with an isoelectric point (p*I*) lower than the antibody to be separated will be charged; c) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream; d) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re–enter first solvent stream; and e) repeating step c) and optionally step d) until the first solvent stream contains the desired purity of antibody.

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Purification of Antibodies

Technical Field

The present invention relates to methods suitable for purification of antibodies, particularly monoclonal antibodies from ascites fluid.

Background Art

The processing of complex biological solutions is a major bottleneck in the biotechnology industry and there is a strong demand for cost effective technologies for the purification of naturally occurring and recombinant proteins. This is particularly true for antibodies including monoclonal antibodies, where there has been an on-going search for simple generic methods of purification. In particular, monoclonal antibodies have had an increasing number of research, therapeutic and diagnostic applications since their initial production in 1975. The difficulties in bioprocessing have meant that recoveries of monoclonal antibodies in existing purification schemes are rarely reported but are often in the range of 10 to 70%. Although new processes have become increasingly effective in terms of yield and recovery, commonly used processes often utilise harsh pH or ionic strength conditions for elution which may not always be compatible with maintaining maximal biological activity of antibodies.

The present inventor has found that preparative electrophoresis using Gradiflow technology (AU 601040) is particularly suitable for the purification of antibodies. In contrast to conventional methods, Gradiflow uses mild, non-denaturing buffers and conditions which may be utilised to produce more active antibody preparations.

Disclosure of Invention

In a first aspect, the present invention consists in a method of separation of an antibody from a mixture of the antibody and at least one contaminant, the method comprising:

(a) placing the antibody and contaminant mixture in a first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane;

(b) selecting a pH for the first solvent stream such that contaminants with an isoelectric point (p*I*) lower than the antibody to be separated will be charged;

(c) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into

the second solvent stream while the antibody is substantially retained in the first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(d) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re-enter first solvent stream; and

(e) repeating step (c) and optionally step (d) until the first solvent stream contains the desired purity of antibody.

Preferably, the antibody and contaminant mixture is a monoclonal antibody in ascitic fluid.

In a preferred embodiment of the first aspect of the present invention, the electrophoretic membrane has a molecular mass cut-off of about 50 to 150 kDa, preferably about 100 kDa. The p*I* of the antibody to be separated is usually obtained by isoelectric focusing (IEF). The pH of the first solvent stream is preferably about 7.5 to 9.5. Major protein contaminants, including albumin whose p*I* is well known to be 4.9, can be separated from the antibodies by being caused to transfer into the second solvent stream at pH 8.3.

In a second aspect, the present invention consists in a method of separation of an antibody from a mixture of the antibody and at least one contaminant, the method comprising:

(a) placing the separated antibody in a first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane;

(b) selecting a pH of the first solvent stream such that the pH is within 1 pH unit of the p*I* of the antibody;

(c) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(d) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the first solvent stream, wherein substantially not causing any

contaminants that have entered the second solvent stream to re-enter first solvent stream; and

(e) repeating step (c) and optionally step (d) until the first solvent stream contains the desired purity of antibody.

The electrophoretic membrane in step (a) preferably has a molecular mass cut-off at least about 200 kDa to ensure the contaminants can pass through to the second solvent stream. A cartridge containing a large 1000 kDa pore size separating-membrane has been found to be particularly suitable for this aspect of the present invention. The pH in step (b) is typically from about 6 to 8.0. It will be appreciated that the pH of the buffer will depend on the p*I* of the antibody to be purified and the p*I*s of the contaminants.

The pH of the buffer used in step (b) can be above or below the p*I* of the antibody to be separated. Preferably, the pH is within 0.5 pH units of the p*I* of the antibody.

In a third aspect, the present invention consists in a method of separation of an antibody from a mixture of the antibody and at least one contaminant, the method comprising:

(a - e) separating the antibody according to the first aspect of the present invention;

(f) placing the separated antibody in a fresh first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane;

(g) selecting a pH of the fresh first solvent stream such that the pH is within 1 pH unit of the p*I* of the antibody;

(h) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the fresh first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(i) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the fresh first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re-enter first solvent stream; and

(j) repeating step (h) and optionally step (i) until the fresh first solvent stream contains the desired purity of antibody.

The molecular mass cut-off of the electrophoretic membrane used in step (f) is preferably larger than the membrane used in step (b). The electrophoretic membrane in step (f) preferably has a molecular mass cut-off at least about 200 kDa to ensure the contaminants can pass through to the second solvent stream. A cartridge containing a large 1000 kDa pore size separating-membrane has been found to be particularly suitable for this aspect of the present invention. The pH in step (g) is typically from about 6 to 8.0. It will be appreciated that the pH of the buffer will depend on the p*I* of the antibody to be purified and the p*I*s of the contaminants.

The pH of the buffer used in step (g) can be above or below the p*I* of the antibody to be separated. Preferably, the pH is within 0.5 pH units of the p*I* of the antibody.

The present inventor has been able to obtain percent recoveries of monoclonal antibodies from ascitic fluid of at least 70% and often greater than 90% using the methods according to the present invention.

In a fourth aspect, the present invention consists in use of Gradiflow in the purification and/or separation of antibodies.

In a fifth aspect, the present invention consists in an antibody purified by the method according to the first, second or third aspects of the present invention.

Throughout this specification, unless the context requires otherwise, the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

In order that the present invention may be more clearly understood, preferred forms will be described in the following examples with reference to the accompanying drawings.

Brief Description of Drawings

Figure 1 shows the operating modes of the Gradiflow separating cartridge. (a) Sized-based separation - this is a first step in which major contaminants are removed downstream from antibody mixture upstream. (b) Charge-based separation - this is a second step suitable to remove any residual contaminants if requiring antibodies of higher purity.

Figure 2 shows SDS-PAGE of the purification of antibody 4. Lane 1 is upstream at 0 min, lanes 2-5 upstream after 10, 20, 30, and 40 min, respectively. Lane 6-9 show downstream at 10, 20, 30, and 40 min, respectively. Lane 10 contains SDS molecular mass markers. Mab=monoclonal antibodies; kDa=Kilodaltons.

Figure 3 shows SDS-PAGE of the purified monoclonal antibodies according to the second aspect of the present invention. Lane 1 and 7 are the SDS-PAGE molecular weight markers. For contrast, the starting material for antibody 1 was placed in lane 2 while lanes 3, 4, 5 and 6 contain the final four product antibodies.

Modes for Carrying Out the Invention

EXPERIMENTAL

Antibodies

The antibodies used in this study were all generated by conventional procedures (Bundesen et al 1985) and supplied to Gradipore Limited by Agen Biomedical Brisbane, Australia as murine ascitic fluids. Table I contains the properties of the target monoclonal antibodies.

Table 1. Monoclonal antibodies (recovery as determined by EIA)

Antibody	Isotype	p*I*	Recovery	
			%	mg/ml antibody
1	IgG1	pH 7.3-7.5	94[a]	8.9
2	IgG2a	pH 6.7-7.7	73[b]	8.1
3	IgG2b	pH 6.6-6.9	79[b]	10.8
4	IgG1	pH 6.8-7.0	71[b]	10.0

[a] - denotes one step purification

[b] - denotes a two-step purification

Gradiflow technology

The separating cartridge of the Gradiflow contains a set of polyacrylamide-based restriction and separating membranes to enable the separation of macromolecules on the basis of size and/or charge (see Figure 1). A range of cartridges is available with M_r cut-offs ranging from 25,000 to 1,000,000. The ability to fractionate proteins over a range of pH and the use

of membranes of different pore sizes enables any target protein to be separated by virtue of its size or isoelectric point.

The Model LM1000 (Gradipore Limited, Sydney, Australia) contains peristaltic pumps, peltier coolers and power supply. It is controlled by a personal computer under a Windows 95 and Lab View format. Alternatively, a manually configured instrument is also available which can operate with conventional peristaltic pumps and power supply (Margolis et al 1995; Corthals et al 1996; Horvath et al 1996; Corthals et al 1997).

Modes of separation

Size-based separation (Figure 1a)

For size separation, a pH is selected at which all proteins have the same charge, in this case negative. Hence all of the proteins from the mixture circulating in the "upstream" compartment will try to migrate into the "downstream" compartment. If a membrane of restrictive pore size is selected, for example the M_r 100,000 used in this case, molecules larger than M_r 100,000 (such as the target antibodies) will be unable to transfer across the membrane and remain upstream. As essentially all proteins in mouse ascitic fluid have p*I* values less than pH 7.7, pH 8.3 was selected for size preparation in this paper. Under these conditions most of the ascitic proteins are transferred "downstream" leaving behind the *M*, 160 000 antibody molecules.

Charged based separation (Figure 1b)

For charge-based separation, a pH is selected between the isoelectric points of two proteins such that one protein will have a positive charge and the other a negative charge. In this example, the protein mixture continuously circulates in the "upstream" compartment. When the current is applied, the negatively charged protein migrates through the membrane to the "downstream" compartment. Continuous circulation of the upstream and downstream compartments allows complete separation of the two proteins.

The vast majority of non-antibody proteins in murine ascitic fluid have isoelectric points below pH 6.5 so that at a pH above pH 6.5, these proteins are negatively charged and will migrate downstream leaving behind the antibody which normally has a p*I* above pH 6.6. For charge separations, a membrane with a large pore size is usually employed (M_r 1 x 10^6) to allow for maximum transport across the membrane.

Purification of monoclonal antibodies

Each sample of ascitic fluid (0.5 - 2 ml) was diluted with at least three volumes of a buffer containing 40 mM Tris-borate, 1 mM EDTA pH 8.3. Firstly a size separation of each sample was carried out in this buffer for 30 to 40 min at 200 V with a M_r cut-off 100,000 separating membrane. Under these conditions, albumin and other impurities rapidly migrated across the membrane leaving behind the purified antibody upstream.

For higher purity, a second run was selected at a pH close to the p*I* of each specific antibody using a M_r cut-off 1×10^6 membrane. For example 40 mM Tris buffer can be adjusted to the required pH with acetic acid. The run time was 40 min at 200 V. The remaining impurities migrated through the membrane while the antibody remained upstream. By taking 50 µl aliquots of upstream and downstream at 10-min intervals during the first and second run, the purity of the target antibodies was then determined by denaturing sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE). The percent recovery was determined by enzyme immunoassay (EIA) after the runs were completed.

The upstream and downstream were harvested after 40 min. For maximum recovery of antibody, a small amount (7 ml) of running buffer was pumped in the upstream and downstream for a minute at the end of the separation process with the current reversed. After the current reversal was switched off, the upstream and downstream were allowed to circulate for another minute before the upstream wash was harvested and combined with the initial antibody harvested. An additional 10-15% of antibody can be recovered in this washing process

Isoelectric focusing

The p*I* of each antibody was determined by running an isoelectric focusing (IEF) gel using a Novex (San Diego CA, USA) IEF gel apparatus as described by the manufacturer. Briefly, the running conditions involved a run time of 1 h at 100 V 1 h at 200 V and 500 V for 30 min. The IEF gel was fixed with a solution of 12% (w/v) trichloroacetic acid (Sigma Product No T8657) with 3.5% (w/v) 5-sulfosalicylic acid (Sigma Product No S-3147) in deionised water for 30 min before staining with Gradipure™ Coomassie Blue.

Determination of antibody purity

Samples were analysed by SDS-PAGE on Gradipore 4-20% T SDS gels [T=(g acrylamide + g *N,N'*-methylenebisacrylamide)/100 ml solution]. The changes to sample purity with time were determined by comparing the protein bands upstream and downstream at different times.

Determination of antibody recovery

Protein concentration

Protein levels in the upstream and downstream were determined by measuring the ultraviolet absorption at 280 nm. A 1 mg/ml solution of mouse monoclonal antibodies was assumed to have an absorbance of 1.2 AU.

Enzyme immunoassay

The antibody activity was determined by a two-site EIA using either antigen or unlabelled sheep anti-mouse immunoglobulin as the capturing component. The microplate was first coated with either 50 µl of antigen (10 µl/ml) or rabbit anti-mouse immunoglobulins (10 µl/ml) Dako (Carpinteria, USA) in phosphate-buffered saline (PBS) pH 7.4 for 1 h at room temperature.

Excess antigen was removed by inverting and tapping the plate and the plate was washed three times with PBS containing 0.1% Tween 20 (PBS/T). Next, 50 µl of a suitable dilution in PBS/T of the monoclonal fraction under test was added and the incubation was allowed to proceed for an hour at room temperature. After removal of unbound antibody by washing, bound antibody was labelled by the addition of a 1/1000 dilution of horseradish peroxidase (HRPO)-labelled anti anti-mouse antibody and incubated for another hour. Finally, the bound enzyme detected after further washing by the addition of substrate and stop solutions.

RESULTS AND DISCUSSION

Isoelectric focusing

IEF is a technique that enables proteins to be characterised by their p*I* values which can be used to determine the best conditions for a charge based separation. An IEF gel of the starting material showed that each ascitic fluid had a unique IEF pattern with the major difference being the position of the multiple bands of target antibodies.

The IEF gel indicated a range of p*I* values from 6.6 to 7.7 for the four different antibodies derived from ascitic fluid samples. The p*I* values of the antibodies are listed in Table 1. The variety of isoforms provides plausible reason for the low recoveries from conventional ion-exchange protocols for

antibodies as the charge heterogeneity could cause multiple broad peaks and tailing effects.

Purification of mouse antibodies

Size separation

Size exclusion was chosen as the first step when IEF (Figure 1) revealed a wide variation in the isoelectric charge of individual antibodies. A membrane with a M_r cut-off of 100,000 was selected as this pore size should retain the M_r 160,000 antibody, yet allow the rapid passage of smaller protein molecules. A pH of 8.3 was chosen so that the majority of immune ascitic fluid proteins had net negative charges at this pH.

A time course for the purification of antibody 4 is depicted in Figure 2. Similar results were obtained for the other three antibodies. After 20 min, the most significant bands in the sample stream are the characteristic heavy and light chains of the monoclonal antibody. Acceptable purity was achieved after 30 min (lane 5 in Figure 2) without substantial improvement at 40 min. Lower-molecular-mass proteins with the most abundant being mouse serum albumin, rapidly passed through the M_r 100,000 membrane leaving behind the antibody upstream. The downstream was harvested every 10 min and showed decreasing amounts of protein in each subsequent harvest (Figure 2, lanes 7-9). Most of the impurities were removed from the antibody in the first 10 min (lane 7) with large amounts of albumin present in the two initial downstream harvests that were collected at 10 min and 20 min. Albumin had disappeared from the upstream after 10 min. This ending was interpreted, as residual albumin found downstream in the 10-min sample being in transit within the separation membrane when the 10-min sample was taken.

These conditions were chosen for initial separation with a view to try to select a universal first step that would allow the purification of any antibody in good yield with the high degree of purity. The Tris-borate buffer was selected because it has proven to be a useful butter for separations under native conditions in many other applications. The voltage was selected on the basis of the required speed of the separation with the aim of completing the process in less than 30 min. For most applications, the higher the voltage the more rapid the purification.

Some antibodies are thought to be labile at room temperature and there are many reports that temperature can affect protein folding with lower temperatures increasing protein volubility.

Charge separation

A higher degree of purity for each antibody can be achieved in a charged-based second step carried out at a pH near the p*I* of each antibody. As the isoelectric points vary, this meant a different pH was selected for each antibody. During the separations using either size or charge, there was no evidence that the solubility of each target antibody was affected by a pH higher than its p*I* or near its p*I*. The solubility of the proteins remained excellent with these operating conditions and choice of buffers used. Each different antibody solution was adjusted with acetic acid to the pH that was close to the p*I* prior to a charge separation. The membrane used for the charge separation was a M_r 1 x 10^6 pore size to increase the speed of removal of the contaminating proteins. Under these conditions, the monoclonal antibody now uncharged, remained upstream and the contaminating negatively charged proteins migrated downstream SDS-PAGE (Figure 3) indicated that a high degree of purity was achieved for all antibodies using this second step. The relatively high p*I* of antibody 1 allowed this antibody to be purified in a single step at pH 8.3 using M_r 1 x 10^6 pore size membrane (instead of M_r 100,000). This antibody was expected to migrate through the M_r 1 x 10^6 membrane because it did have a small negative charge at this pH but for short runs of less than an hour, it remained upstream. Indeed with longer separation times (1-2 h) some migration downstream was noted.

Recovery

The recovery of the monoclonal antibodies was determined by comparing the final biological activity of the antibody present upstream, downstream and in the washes with the starting material (Table I). Although recoveries for antibodies 2, 3 and 4 (using two-stage purifications) were less than for antibody 1 (Table 1) quantities of >8 mg of each antibody were recovered per ml of ascitic fluid. This recovery was higher than the expected yields for other purification procedures. These higher activities recovered may be due to a combination of the mild buffers used the relatively short distance required for separation to occur with the separation cartridge and the short purification times.

The protocol developed takes the advantage of the large size (M_r 160,000) of the monoclonal antibodies relative to other proteins in ascitic fluid and their relatively high p*I* values compared to other proteins in murine ascitic fluid. The protocol described here is less complex than conventional chromatographic purification techniques where more variables need to be considered. The immunoglobulin fraction is usually about 2-25% of the total protein in ascitic fluids. The high content of lipid present in ascitic fluid is know to reduce the life of fractionation columns. In the present experiments, excellent purification and recovery without the need to delipidise or pretreat the samples was achieved.

Initially, small amounts (10-20 mg) of each target antibody were purified to test the invention. Linear scale up from the 15 cm^2 membranes (used here) to 200 cm^2 has been accomplished by the present inventor and co-workers previously for haemoglobin/albumin separations (Horvath et al 1994). Preliminary scale up from 2 ml to 10 ml of mouse ascites fluid on the 15 cm^2 cartridges was achieved. Longer processing time or a larger separation cartridges may be required for larger quantities of proteins.

Comparison of antibodies separated according to the present invention with the same antibodies purified by standard techniques including Protein-A, Protein-G and ion exchange chromatography by a collaborating third party revealed the antibodies obtained by the present invention were more active. Furthermore, the yields of antibodies were greater using the present invention. Tables 2 and 3 show the results of the comparisons of several purifications of antibodies.

Table 2. Yield of Mouse IgG1 monoclonal antibody

Purification Method	Yield (mg antibody recovered)
Protein-A	65
Invention	68
Ion exchange	60

Table 3. Yield of Rat IgG2b monoclonal antibody

Purification Method	Yield (%)
Protein-G	83
Invention	91
Ion exchange	81

Electrophoretic analysis (SDS-PAGE) of antibodies purified by the present invention revealed lower number of protein bands indicating that the present method does not cleave or damage the antibodies compared with other purification techniques. Not only can the present invention provide greater yields of antibody, the invention also provides more active and less denatured antibody preparations.

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

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Horvath ZC, Gooley AA, Wrigley CW, Margolis J and Williams KL. Preparative affinity membrane electrophoresis. Electrophoresis 1996 *17* 224-226.

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CLAIMS:

1. A method of separation of an antibody from a mixture of the antibody and at least one contaminant, the method comprising:

(a) placing the antibody and contaminant mixture in a first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane;

(b) selecting a pH for the first solvent stream such that contaminants with an isoelectric point (p*I*) lower than the antibody to be separated will be charged;

(c) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(d) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re-enter first solvent stream; and

(e) repeating step (c) and optionally step (d) until the first solvent stream contains the desired purity of antibody.

2. The method according to claim 1 wherein the antibody and contaminant mixture is a monoclonal antibody in ascitic fluid.

3. The method according to claim 1 or 2 wherein the electrophoretic membrane has a molecular mass cut-off of 50 to 150 kDa.

4. The method according to claim 3 wherein the electrophoretic membrane has a molecular mass cut-off of 100 kDa.

5. The method according to any one of claims 1 to 4 wherein the pH of the first solvent stream is 7.5 to 9.5.

6. The method according to any one of claims 1 to 5 further including the steps of:

(f) placing the separated antibody in a fresh first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane;

(g) selecting a pH of the fresh first solvent stream such that the pH is within 1 pH unit of the p*I* of the antibody;

(h) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the fresh first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(i) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the fresh first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re-enter fresh first solvent stream; and

(j) repeating step (h) and optionally step (i) until the fresh first solvent stream contains the desired purity of antibody.

7. The method according to claim 6 wherein the molecular mass cut-off of the membrane used in step (f) is larger than that used in step (b).

8. The method according to claim 7 wherein the molecular mass cut-off of the electrophoretic membrane used in step (f) is at least 200 kDa.

9. The method according to claim 8 wherein the molecular mass cut-off of the electrophoretic membrane used in step (f) is 1000 kDa.

10. The method according to any one of claims 6 to 9 wherein the pH in step (g) is from 6 to 8.

11. The method according any one of claims 6 to 9 wherein the pH in step (g) is within 0.5 pH units of the p*I* of the antibody.

12. The method according to any one of claims 1 to 11 wherein percent recovery of the antibody is at least 70%.

13. The method according to claim 12 wherein percent recovery of the antibody is at least 90%.

14. A method of separation of an antibody from a mixture of the antibody and at least one contaminant, the method comprising:

(a) placing the separated antibody in a first solvent stream, the first solvent stream being separated from a second solvent stream by an electrophoretic membrane;

(b) selecting a pH of the first solvent stream such that the pH is within 1 pH unit of the p*I* of the antibody;

(c) applying an electric potential between the two solvent streams causing movement of at least some of the contaminants through the membrane into the second solvent stream while the antibody is substantially retained in the

first solvent stream, or if entering the membrane, being substantially prevented from entering the second solvent stream;

(d) optionally, periodically stopping and reversing the electric potential to cause movement of any antibody having entered the membrane to move back into the first solvent stream, wherein substantially not causing any contaminants that have entered the second solvent stream to re-enter first solvent stream; and

(e) repeating step (c) and optionally step (d) until the first solvent stream contains the desired purity of antibody.

15. The method according to claim 14 wherein the antibody and contaminant mixture is a monoclonal antibody in ascitic fluid.

16. The method according to claim 14 or 15 wherein the molecular mass cut-off of the electrophoretic membrane used in step (a) is at least 200 kDa.

17. The method according to claim 16 wherein the molecular mass cut-off of the electrophoretic membrane used in step (a) is 1000 kDa.

18. The method according to any one of claims 14 to 17 wherein the pH in step (b) is from 6 to 8.

19. The method according to any one of claims 14 to 17 wherein the pH in step (b) is within 0.5 pH units of the p*I* of the antibody.

20. An antibody purified by the method according to any one of claims 1 to 19.

21. The antibody according to claim 20 being a monoclonal antibody.

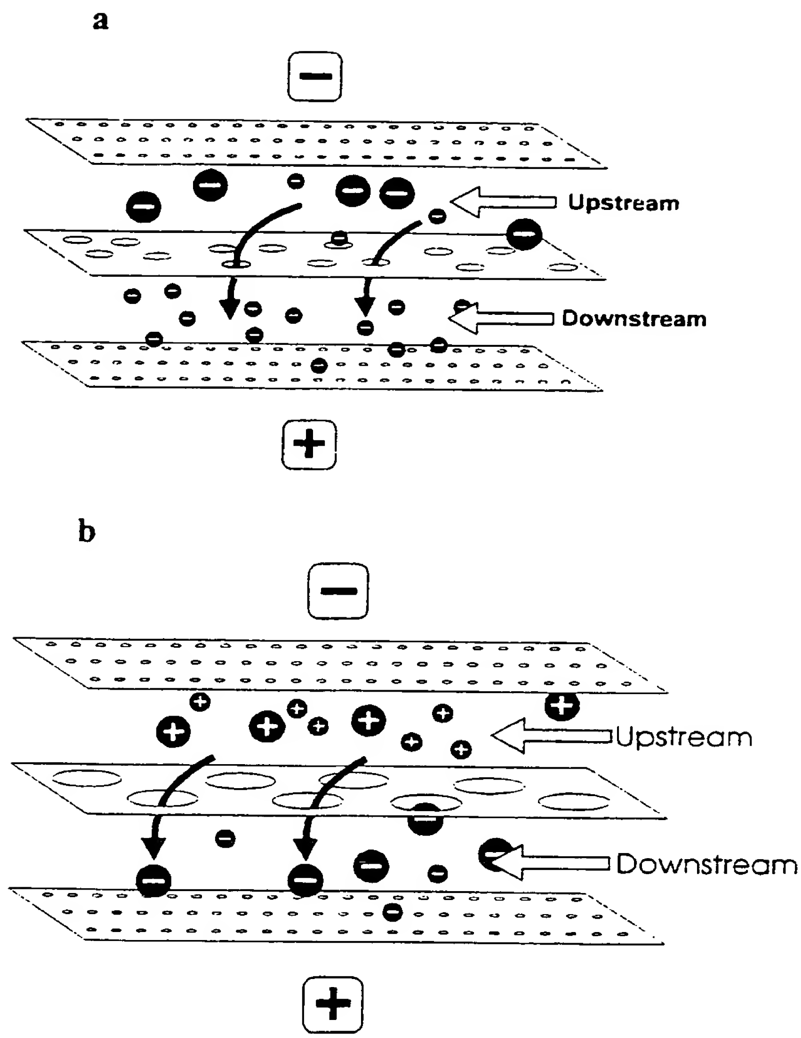
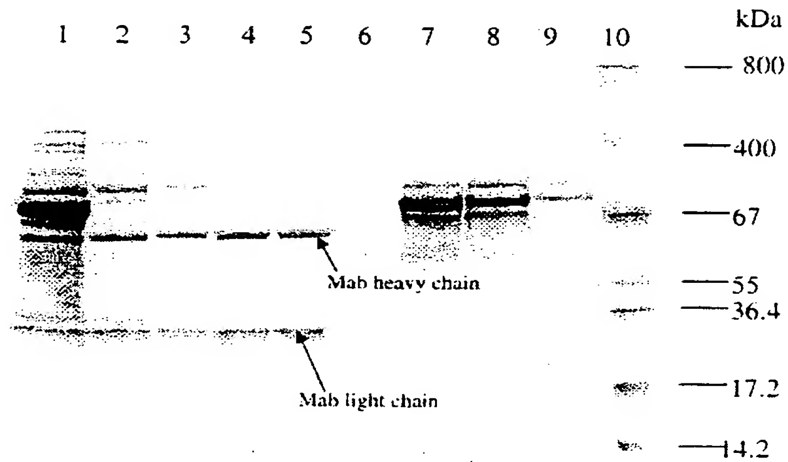


Figure 1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kDa
800
400
67
55
36.4
17.2
14.2
Mab heavy chain
Mab light chain

Figure 2

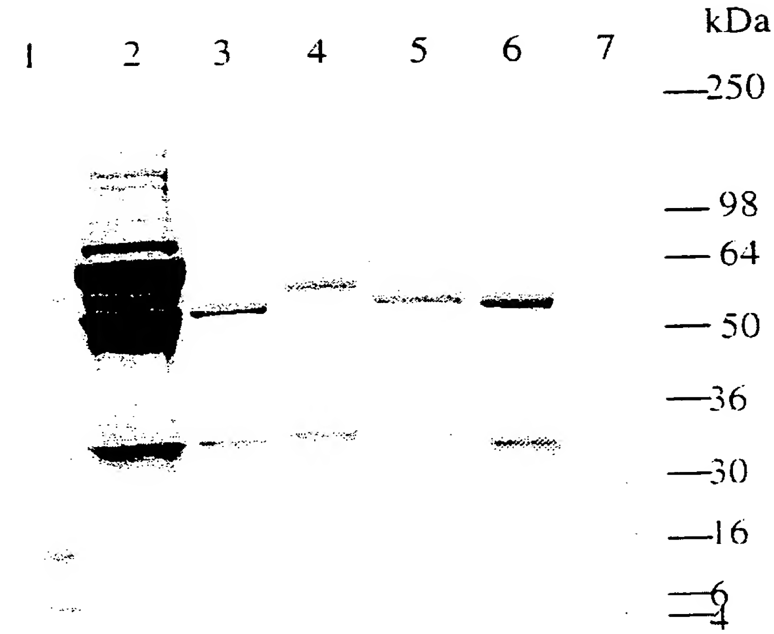

Figure 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 99/00424

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: C07K 1/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Separate Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	Journal of Chromatography A, 827 (1998) 329-335 "Purification of monoclonal antibodies from ascitic fluid using preparative electrophoresis"; S Lim et al	1-21
X Y	Electrophoresis, (1994), Vol.15 (7), pages 968-971 "Multifunctional apparatus for electrokinetic processing of proteins"; Z. Stephen Horvath et al	1-21 1, 6, 14
Y	Electrophoresis, (1995), Vol.16 (1), pages 98-100 "Preparative reflux electrophoresis"; Joel Margolis et al	1, 6, 14

☐ Further documents are listed in the continuation of Box C

☐ See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 June 1999	05 JUL 1999

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

STN: File WPIDS. Keywords: (antibod? and (purif? or separat?) and (electrophor? or isoelectric)
File CA. Keywords: (antibod? and (purif? or separat?) and electrophor? and isoelectric and ascit?)
File MEDLINE. Keywords: (antibod? and (purif? or separat?) and electrophor? and isoelectric and ascit?)

ORBIT: File WPAT. Search terms
1. C07K 1/14 and antibod: and electrophor:
2. C07K 3/14 and antibod:
3. C07K 1/26.